Canadian Centre for Occupational Health and Safety

Centre canadien d'hygiène et de sécurité au travail

RADIOFREQUENCY RADIATION IN THE WORKPLACE

P89-24E

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Canadian Centre for Occupational Health and Safety

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RADIOFREQUENCY RADIATION IN THE WORKPLACE

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1. INTRODUCTION

Communications, industry and medicine are increasingly using radiofrequency electromagnetic fields. As a result, there is a greater need to understand the known and possible health consequences of exposure to these fields. This publication briefly summarizes the current state of knowledge concerning health effects of exposure to radiofrequency electromagnetic fields. For more detailed information, consult the "Further Reading" list or contact the Canadian Centre for Occupational Health and Safety.

2. WHAT IS RADIOFREQUENCY (RF) ELECTROMAGNETIC RADIATION?

Electromagnetic radiation is all around us. It includes a broad range of forms. Waves of radiofrequency radiation transmit radio and television broadcasts. Waves of microwave radiation in microwave ovens cook food. Waves of infrared rays from the sun heat the earth.

Radiofrequency and microwave radiation are part of the electromagnetic spectrum. Although this spectrum is divided into many different frequency bands, it can be broadly separated into two groups--ionizing radiation and non-ionizing radiation (Figure 1).

The ionizing part of the electromagnetic spectrum includes x-rays and gamma rays. Ionizing electromagnetic radiation is high frequency and high energy radiation. When a material absorbs x-rays or gamma rays, the energy absorbed may be enough to eject electrons from atoms or molecules, producing ions.

The non-ionizing part of the electromagnetic spectrum includes all the frequencies from extremely low frequency fields (ELF), through visible light, to ultraviolet light. Radiofrequency radiation generally does not change the atomic or molecular structure of the human body when it is absorbed.

Radiofrequency (RF) radiation is part of the non-ionizing radiation spectrum. The term RF is often used for the frequency range from 10 kHz (kilohertz, one thousand hertz) to 300 MHz (megahertz, one million hertz). Microwave frequencies range from 300 MHz to 300 GHz (gigahertz, one billion hertz). This publication uses the term RF radiation to describe all frequencies from 10 kHz to 300 GHz.

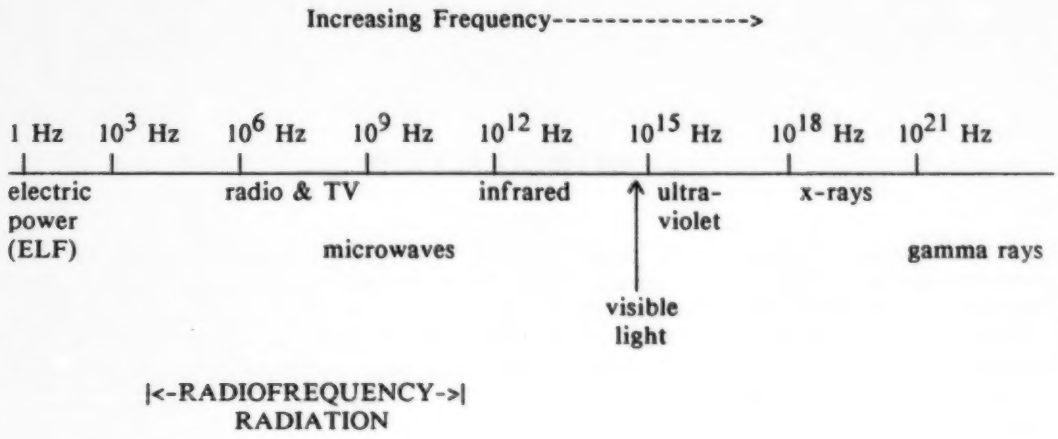

Figure 1 - The electromagnetic spectrum

RF radiation travels in waves. A combination of electric and magnetic fields create a wave of electromagnetic energy. Levels of RF radiation are usually given in terms of:

- power density, expressed in milliwatts per square centimeter (mW/cm^2)
- electric field strength, expressed in units of volts per meter (V/m)
- magnetic field strength, expressed in units of amperes per meter (A/m)

The human body can absorb, transmit or reflect RF fields. The amount of RF energy it absorbs is an important factor in determining whether the RF exposure is harmful.

The body's absorption of energy depends on several factors, including the size, shape and position of the body in the field, and the frequency of the RF field. The range of frequencies in which the body absorbs maximum energy is known as the resonant frequency range. For the average person, it is between 30 MHz and 300 MHz. As Table 1 shows, FM and VHF-TV transmitters and some types of industrial RF heaters emit electromagnetic radiation in this frequency range.

3. WHO IS AT RISK FROM RF EXPOSURE?

There are many sources which produce RF radiation. Operators of these devices and other personnel in the vicinity may be at risk from exposure to RF radiation. Table 1 summarizes these sources and their uses in the workplace.

Table 1 - Some occupational sources of RF radiation

Sources	Uses	Frequency Range
Dielectric heaters	Seal/emboss plastics; cure glues, resins, particle boards, panels; bake sand cores; mold appliance covers and auto parts; heat paper products.	1-100 MHz; mainly 27.12 MHz
Induction heaters	Deep hardening; forging; welding; soft soldering; brazing; annealing; tempering metals and semi-conductors.	60 Hz-27 MHz; mainly 250-500 kHz
Microwave heaters	Drying wood, paper, film, inks; thawing, cooking, baking, (including dehydrating, and pasteurizing) sterilizing food.	915 and 2450 MHz
Broadcast	AM radio FM radio Very High Frequency (VHF) TV Ultra High Frequency (UHF) TV	535-1605 kHz 88-108 MHz 54-72, 76-88, 174-216 MHz 470-890 MHz
Communications	Fixed systems: tropospheric scatter; satellite communication; microwave point-to-point (relay); high-frequency radio.	0.8-15GHz
	Mobile systems: CB radios; walkie-talkies; cellular phones.	27-800 MHz
Radar	Acquisition and tracking; air and auto traffic control; marine uses; surveillance.	1-15 GHz (pulsed)
Welding	Production of pipe, tube, and beam; spot welding.	0.4-100 MHz
Diathermy	Produce local heating in tissue.	13.56 and 27.12 MHz; 915 and 2450 MHz

Source: Non-Ionizing Radiation Guide Series. American Industrial Hygiene Association, 1988.

Note: Typical levels of RF radiation emitted by many of these devices can be found in the Non-Ionizing Radiation Levels Data Base. For more details, contact CCOHS.

4. WHAT ARE THE HEALTH EFFECTS OF RF EXPOSURE?

RF fields produce various health effects in the body. Absorption of sufficient RF energy heats tissue and can produce harmful "thermal effects." "Non-thermal" effects have also been observed at RF levels too low to increase body temperature.

Thermal Effects

The body has a "thermostat" which maintains a temperature of 37C, despite widely varying environmental conditions. Increased blood flow to the skin and sweating dissipates excess heat. When the body is unable to dissipate the excess heat, its temperature rises.

In general, an increase in body temperature of 6C can cause death. Increases of 5C have been associated with heat stroke and brain damage. Elevated temperatures reduce fertility in men, and can cause birth defects in the fetus.

RF energy heats the body in the same way as a microwave oven heats food. If the body absorbs high levels of energy, its temperature rises or heating occurs at localized areas. At lower levels, the body's "thermostat" may be able to dissipate the excess heat. The eyes, gonads and brain are the organs most sensitive to thermal effects. Exposure to RF power densities of about 10 mW/cm^2 or more could produce measurable heating of tissue.

In experiments with laboratory animals, intense levels of RF fields have produced many effects. Brief whole body exposures of less than 5 minutes to strong RF fields have resulted in birth defects and reduced fetus size. Localized exposure to intense fields have resulted in severe burns. A single short exposure of the eye to intense RF fields (for example, above 100 mW/cm^2) produced cataracts. For more information on the ocular effects of microwave radiation, see the CCOHS publication, P89-13E "The Effect of Microwaves on the Eye."

Exposure to certain types of RF fields produces an effect known as "microwave hearing." It is an auditory effect described as a click, buzz or chirp. It is believed that short pulses of microwave energy cause small, but rapid thermal expansions of the skull. These are then conducted by bone to the inner ear and sensed as sounds. The effect stops when exposure is discontinued. Although not considered a health hazard, the experience may be annoying and stressful.

Non-Thermal Effects

Exposures to weak RF fields do not increase body temperature, although they can affect the central nervous system, the cardiovascular system and the reproductive system. Some persons working in low-level RF fields report headaches, eyestrain, fatigue, loss of appetite, and sleep disturbance. These reports may be related to the effects on the nervous system, and are reversible if exposure is discontinued. Some experts report that the weak fields may act as a stressor. These effects are still neither very well understood nor consistently identified.

Some reports suggest that weak RF radiation increases the risk of cancer, particularly leukemia and brain cancer, in children and workers exposed to electromagnetic radiation. In most cases, the suggested association refers to exposure to power-line frequency (60 Hz) fields, rather than radiofrequencies. None of the studies which link electromagnetic field exposure to an increased risk of cancer are conclusive. Research in this area is continuing.

It is not clear what levels of RF radiation will produce a particular effect nor how they occur. Experts recommend that exposures be kept below applicable guidelines (see Section 6).

Under certain circumstances, RF radiation may interfere with the operation of implanted cardiac pacemakers. For more details, consult CCOHS publication "Possible health hazards for cardiac pacemaker wearers from exposure to electromagnetic fields," P88-5E.

5. WHAT ARE THE RF SAFETY HAZARDS?

Radiofrequency fields can charge metal objects, such as vehicles, fences, umbrellas, metal roofs and other ungrounded, or poorly grounded objects, even people. Electric shocks or RF burns result when a person touches a charged object, or when a charged person contacts a grounded metal object. The electric current flowing through the body from charged objects causes the shocks or burns. An electric shock can be felt as a tingling or prickling sensation, or as a more severe and possibly painful shock. In general, the lower the frequency, the higher the risk of shock hazard. Shock and burn hazards occur at frequencies below about 100 MHz.

Burns are caused by a high current density at the point of contact on the body. For example, burns occur when the current entering the body, through contact by the fingers with a charged object, exceeds 200 mA.

Radiofrequency fields may also activate electro-explosive devices or ignite flammable materials or mixtures under certain circumstances. RF radiation may also interfere with sensitive electronic equipment. Accidents have been attributed to a malfunction in equipment due to radiofrequency interference.

6. WHAT ARE THE RF EXPOSURE LIMITS?

Health and Welfare Canada's Safety Code-6 gives recommended exposure limits to RF fields between 10 MHz and 300 GHz. Appendix A summarizes these limits. The Safety Code applies to persons employed in Federal Public Service Departments and Agencies, and others coming under the jurisdiction of the Canada Labour Code. A proposed revision to this guideline covers frequencies to 10 kHz and includes limits for contact currents, discussed in Section 5. The revision, which will replace Safety Code-6, is expected to be published by Health and Welfare Canada in 1990. Appendix B summarizes the proposed revisions.

For most other workers, the individual provinces or territories are responsible for RF radiation protection. Some provinces use the federal limits as a guideline for limiting RF radiation exposure. Others use the Threshold Limit Values (TLVs) set out by the American Conference of Governmental Industrial Hygienists (ACGIH). Appendix C summarizes these limits, as well as other RF standards and guidelines from other countries or organizations. The guidelines are provided as information only and should only be applied by qualified professionals after consulting the original documents.

Appendix D lists the federal, provincial, and territorial agencies to contact regarding RF radiation protection and regulations.

7. HOW CAN YOU CONTROL OR LIMIT EXPOSURE TO RF RADIATION?

Health and Welfare Canada's Safety Code-6 sets out safety requirements for installing and using RF devices. For full details, consult the Further Reading list or contact the appropriate radiation protection authority as listed in Appendix D.

Prevent RF shocks by thoroughly grounding or enclosing conductors. Also, use safety interlocks on RF sources to prevent accidental exposures. Restrict exposure to RF radiation by using various controls, such as shielding the source, isolating the source a safe distance away from personnel, or limiting the durations of exposure. Post signs, which warn people of possible RF hazards, on access panels of RF equipment and at places where workers could be exposed to RF radiation.

Levels of RF radiation to which workers could be exposed should be checked to ensure compliance with applicable guidelines. Only qualified professionals, using proper instrumentation, should measure RF radiation.

It is prudent to adopt a recommendation of the ACGIH which states: "Needless exposure to all radiofrequency radiation exposures should be avoided given the current state of knowledge on human effects, particularly non-thermal effects."

Note: The Non-Ionizing Radiation Levels Data Base, available from CCOHS, provides typical levels of radiofrequency radiation and other non-ionizing radiation from various sources in the workplace. (For more information, contact CCOHS.)

APPENDIX A

Summary of Existing Canadian Occupational Radiofrequency Radiation Exposure Guidelines (Safety Code-6)

Frequency Range	Electric Field (V/m)	Magnetic Field (A/m)	Power Density (mW/cm^2)
Whole body			
10 MHz-1 GHz (1 hour)	60	0.16	1
(1 minute)	300	0.8	25
1 GHz-300 GHz (1 hour)	140	0.36	5
(1 minute)	300	0.8	25
Extremities			
10 MHz-300 GHz (1 hour)	200	0.5	10
(1 minute)	300	0.8	25

Source: Recommended safety procedures for the installation and use of radiofrequency and microwave devices in the frequency range 10 MHz-300 GHz (Safety Code, 6). Ottawa: Department of National Health and Welfare, 1979.

APPENDIX B

Summary of Proposed Revision to Canadian Occupational Radiofrequency Radiation Exposure Recommendations

Frequency Range	Electric Field (V/m)	Magnetic Field (A/m)	Equivalent Power Density (mW/cm^2)
0.01-1.2 MHz	600	4.0	--
1.2-3 MHz	600	4.8/f	--
3-30 MHz	*1800/f or $3120/f^{1.5}$	4.8/f	--
30-100 MHz	*60 or 20	0.16	--
100-300 MHz	*60 or 0.2f	0.16	1
300 MHz-1.5 GHz	$3.45f^{0.5}$	$0.0093f^{0.5}$	--
1.5 GHz-300 GHz	140	0.36	5

Contact-Current Limits for Occupational Exposures (Canadian Proposal)

Frequency range	Current (mA)
10 kHz-100 kHz	$40(10f)^{0.7}$
100 kHz-100 MHz	40

Source: Stuchly, M.A. Proposed revision of the Canadian recommendations on radiofrequency-exposure protection. Health Physics. Vol. 53, no. 6 (1987) p. 649-665.

* Lower limits apply when the exposed person is separated less than 0.1m from electrical ground; in all other cases the higher limits apply.

f = frequency in MHz

APPENDIX C

Other Occupational Radiofrequency Standards or Guidelines

Country or Organization	Frequency Range	Electric Field (V/m)	Magnetic Field (A/m)	Equivalent Power density (mW/cm^2)
American Conference of Governmental Industrial Hygienists[1]	10 kHz-3 MHz	614	1.63	100
	3 MHz-30 MHz	1842/f	5/f	$900/f^2$
	30 MHz-100 MHz	61.4	0.16	1
	100 MHz-1 GHz	$6.14\sqrt{f}$	$0.016\sqrt{f}$	f/100
	1 GHz-300 GHz	194	0.5	10
American National Standards Institute[2]	0.3 MHz-3 MHz	632	1.6	100
	3 MHz-30 MHz	1897/f	4.7f	$900/f^2$
	30 MHz-300 MHz	63.2	0.16	1.0
	300 MHz-1.5 GHz	$3.65\sqrt{f}$	$9.13\times10^{-3}\sqrt{f}$	f/300
	1.5 GHz-100 GHz	141	0.35	5.0
International Radiation Protection Association[3]	0.1 MHz-1 MHz	614	1.6/f	--
	1 MHz-10 MHz	614/f	1.6/f	--
	10 MHz-400 MHz	61	0.16	1
	400 MHz-2 GHz	$3\sqrt{f}$	$.008\sqrt{f}$	f/400
	2 GHz-300 GHz	137	0.36	5
National Radiological Protection Board (UK)[4] (2 hours/day)	10 kHz-50 kHz	2000	100	--
	50 kHz-300 kHz	2000	5/f	--
	300 kHz-10 MHz	600/f	5/f	--
	10 MHz-30 MHz	60	5/f	--
	30 MHz-100 MHz	60	0.16	1
	100 MHz-500 MHz	$6\sqrt{f}$	$0.016\sqrt{f}$	f/100
	500 MHz-300 GHz	135	0.36	5
West Germany[5]	10 kHz-30 kHz	1500	350	--
	30 kHz-2 MHz	1500	7.5/f	--
	2 MHz-30 MHz	3000/f	7.5/f	--
	30 MHz-3 GHz	100	0.25	2.5
	3 GHz-12 GHz	$100\sqrt{(f/3000)}$	$0.25\sqrt{(f/3000)}$	2.5f/3000
	12 GHz-3000 GHz	200	0.5	10
National Institute for Occupational Safety and Health (U.S.A.)[6]	0.3 MHz-3 MHz	434	1.15	50
	3 MHz-30 MHz	1302/f	3.5/f	$450/f^2$
	30 MHz-300 MHz	43.4	1.14	0.5
	300 MHz-3 GHz	2.5f	6.7×10^{-3}f	f/600
	3 GHz-300 GHz	137.3	0.365	5

f = frequency in MHz

Country or Organization	Frequency Range	Electric Field (V/m)	Magnetic Field (A/m)	Equivalent Power density (mW/cm^2)
Czechoslovakia (current)[7]	0.03 MHz-30 MHz	50	--	--
	30 MHz-300 MHz	10	--	--
	0.3 MHz-300 GHz	--	--	0.025cw
	0.3 MHz-300 GHz	--	--	0.001p
(proposed)	0.03 MHz-10 MHz	70	--	--
	10 MHz-70 MHz	700/f	--	--
	70 MHz-300 MHz	10	--	--
	0.3 GHz-300 GHz	--	--	0.025
USSR[7]	0.06 MHz-3 MHz	50	5	--
	3 MHz-30 MHz	20	--	--
	30 MHz-50 MHz	10	0.3	--
	50 MHz-300 MHz	5	--	--
	300 MHz-300 GHz	--	--	0.2/t
Australia[8]	300 kHz-3 MHz	614	1.6	100
	3 MHz-30 MHz	1840/f	5/f	$900/f^2$
	30 MHz-300 GHz	61.4	0.16	1
Sweden[9]	10 MHz-300 MHz	--	--	5
	300 MHz-300 GHz	--	--	25
Italy[9]	300 kHz-3 MHz	140	0.36	5
	3 MHz-300 GHz	60	0.17	1

f = frequency in MHz
cw = continuous waves
p = pulsed waves
t = time in hours

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APPENDIX D

Agencies Responsible for Radiofrequency Radiation Protection

Federal

Non-Ionizing Radiation Section
Bureau of Radiation and Medical Devices
Health and Welfare Canada
Room 233, Environmental Health Centre
Tunney's Pasture
Ottawa Ontario K1A 0L2
(613) 954-0307

Alberta

Radiation Health Branch
Occupational Health and Safety Division
4th Floor
10709 Jasper Avenue
Edmonton Alberta T5J 3N3
(403) 427-2691

British Columbia

Radiation Protection Service
BC Ministry of Health
200 - 307 West Broadway
Vancouver BC V5Y 1P9
(604) 660-6633

Manitoba

Workplace Safety and Health Division
Department of Labour
1000 - 330 St Mary Avenue
Winnipeg Manitoba R3C 3Z5
(204) 945-3452

New Brunswick

Radiation Protection Service
New Brunswick Department of Health
and Community Services
P O Box 5100
Fredericton New Brunswick E3B 5G8
(506) 453-2067

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Newfoundland

Occupational Health and Safety Services
Department of Labour
P O Box 4750
St John's Newfoundland A1C 5T7
(709) 576-5548

Northwest Territories

Occupational Health Section
Safety Division
Department of Justice
P O Box 1320
Yellowknife NWT X1A 2L1
(403) 873-7996

Nova Scotia

Department of Health and Fitness
7th Floor
Joseph Howe Building
P O Box 488
Halifax Nova Scotia B3J 2R8
(902) 424-4077

Ontario

Radiation Protection Service
Special Studies and Services Branch
Occupational Health and Safety Division
Ontario Ministry of Labour
81 Resources Road
Weston Ontario M9P 3T1
(416) 235-5922

Prince Edward Island

Division of Community Hygiene
Department of Health and Social Services
P O Box 2000
Charlottetown PEI C1A 7N8
(402) 368-4975

Quebec

Commission de la sante et de la
securite du travail (CSST)
1199, rue de Bleury
CP 6056 succ. A
Montreal Quebec H3C 4E1
(514) 873-7545

Saskatchewan

Radiation Safety Unit
Occupational Health and Safety Branch
Department of Human Resources
Labour and Employment
1870 Albert Street
Regina Saskatchewan S4P 3V7
(306) 787-4538

Yukon Territory

Health Services
Department of Health and Human Resources
P O Box 2703
Whitehorse Yukon X1A 2C6
(403) 667-5202

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